Insignificance of Radiotoxicity of Spallation Products in an Accelerator-Driven Transmutation System

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I. Introduction

One of the concerns facing accelerator-driven transmutation systems (ADSs) is whether the radiotoxicity of materials produced during the transmutation process poses more of a concern than does the radiotoxicity of the spent nuclear fuel (SNF) itself. Most of the common fission products (or FPs) are emitters of beta radiation, but additionally, some of the radionuclides generated during spallation are alpha emitters. Thus, both ingestion and inhalation radiotoxicity of the materials produced during spallation could be significant.[1] Typically, ingestion is considered to be more significant than inhalation radiotoxicity for long-term storage/disposal (such as in a repository) because the greatest potential biological hazard to humans occurs when the isotope is absorbed in nearby ground water or brine and transported from the repository to drinking water. Nonetheless, inhalation radiotoxicity is also important to analyze in case of a breach of containment inside the accelerator facility and/or for short-term (i.e., above-ground) storage concerns. Thus, this study calculated the radiotoxicity of spallation products (or SPs) from three different targets: lead-bismuth eutectic (LBE), LBE-cooled tungsten, and LBE-cooled lead.

II. Description

The codes MCNPX and CINDER90 were used to calculate the depletion and decay of radioisotopes in a target over an assumed 60-year operating time.[2,3] Spallation product inventories were normalized to 1 metric ton of SNF from a light water reactor (LWR) being transmuted and 5 tons of natural uranium ore (to make 1 ton of enriched UO_2 fuel, 5 tons of natural ore is required). Figures 1 and 2 compare the ingestion and inhalation radiotoxicities, respectively, for an incoming proton beam energy of 1 GeV for the three different targets.[4] The results are compared to the radiotoxicity of natural uranium ore and that of typical SNF without transmutation.[5]

III. Results

Figure 1 shows that the ingestion radiotoxicities of spallation products (especially from LBE targets) are significantly greater than that of fission products from transmutation for the first year, but not thereafter. The ingestion radiotoxicities of spallation products decrease to less than 10 times that of natural uranium ore within 10 years and less than that of natural uranium ore within a few hundred years, as do fission product radiotoxicities. Lead and LBE spallation products pose a greater inhalation hazard than fission products in the first 6 months but decay quickly, whereas the inhalation radiotoxicity from tungsten spallation products is greater than that of fission products for several hundred years, at which point they both decay below that of natural uranium ore anyway. Thus, the results show that spallation products do not pose a significant long-term radiotoxicity hazard but can be important in short-term storage facilities.

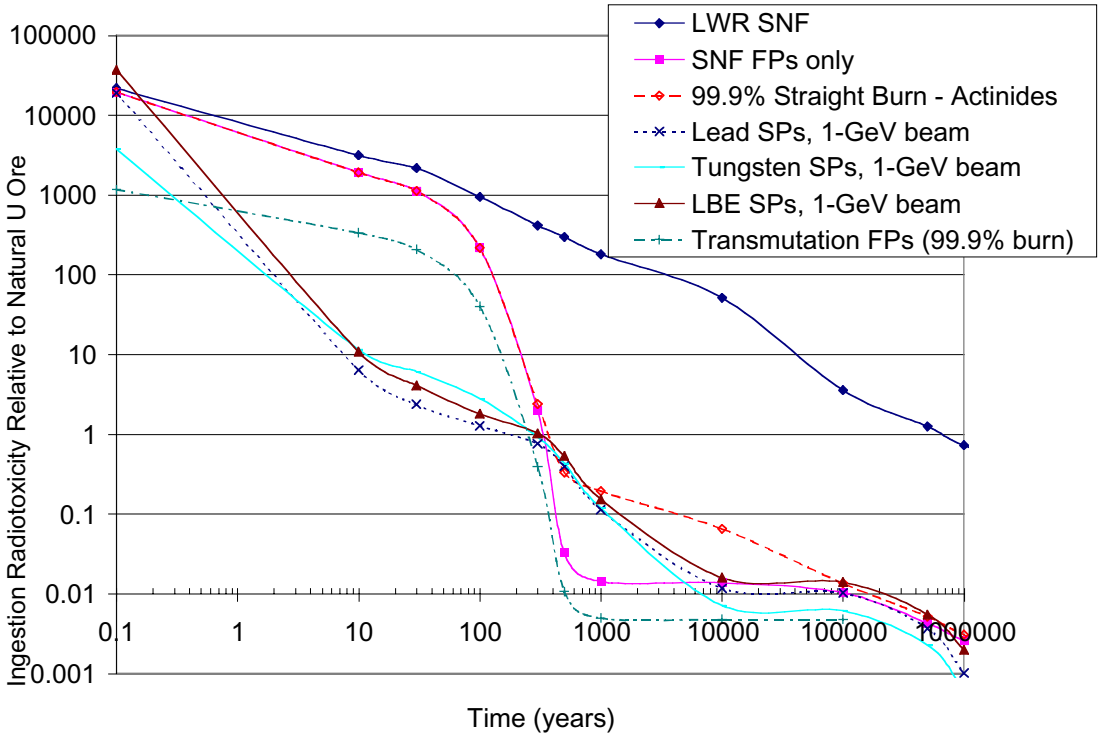

Fig. 1. Ingestion radiotoxicity of spallation products compared with SNF.

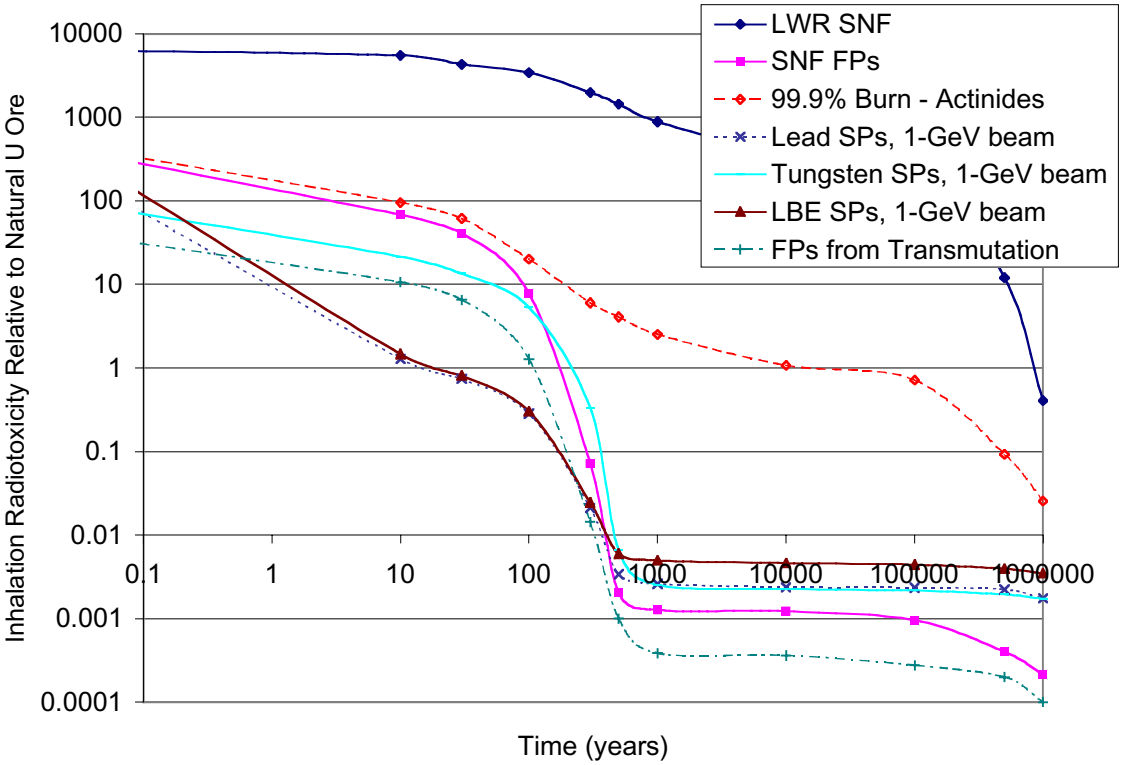

Fig. 2. Inhalation radiotoxicity of spallation products compared with SNF.

Radiotoxicity increases approximately linearly with proton beam energy. Thus, at a proton beam energy of 1.6 GeV, both the ingestion and inhalation radiotoxicities are approximately twice that present at 800 MeV, and so on. Thus, to decrease the radiotoxicity risk, the proton beam energy must be adjusted accordingly (however, the greater the energy, the more efficient the spallation process). Polonium-210 plays the biggest role for ingestion and inhalation radiotoxicity initially (it is present in all three targets because all targets are LBE-cooled). However, after 10 years, ^{207}Bi and ^{194}Hg contribute the most to ingestion radiotoxicity for the lead and lead-bismuth targets, whereas ^{148}Gd definitely plays the biggest role for ingestion radiotoxicity in the tungsten target and for inhalation radiotoxicity in all of the targets.

References

1. Alexey Stankovsky et al., Accumulation and Transmutation of Spallation Products in the Target of Accelerator-Driven System, *Journal of Nuclear Science and Technology*, Vol. 38, No. 7, pp. 503—510 (July 2001).

2. Laurie S. Waters, ed, MCNPX™ User s Manual, Version 2.1.5, Los Alamos National Laboratory report LA-UR 99-6058 (November 15, 1999).

3. W. B. Wilson et al., Recent Development of the CINDER'90 Transmutation Code and Data Library for Actinide Transmutation Studies," *Proc. GLOBAL'95 Int. Conf. on Evaluation of Emerging Nuclear Fuel Cycle Systems*, Versailles, France, September 11—14, 1995, p. 848 (1995).

4. Trellue, H.R., (The Answer is No) Does Transmutation of Spent Nuclear Fuel Produce More Hazardous Material Than It Destroys? *Radwaste Solutions*, American Nuclear Society (July/August 2002), pgs. 40-43.

5. Van Tuyle, G.J., et al., Candidate Approaches for an Integrated Nuclear Waste Management Strategy Scoping Evaluations, Los Alamos National Laboratory report LA-UR- 01-5572 (November 2001).